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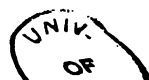
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ARTES SCIENTIA VERITA.

THREE REPORTS
ON THE USE OF
THE STEAM COALS
OF THE
"HARTLEY DISTRICT"
OF
NORTHUMBERLAND
IN
MARINE BOILERS.

BY
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INST. OF MINING ENGINEERS;
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UNIVERSITY OF DURHAM, &c.

Newcastle-on-Tyne:
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1858.



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FIRST REPORT.

TO THE STEAM COLLIERIES' ASSOCIATION, NEWCASTLE-
UPON-TYNE.

GENTLEMEN,

1.—The length of time that has elapsed, since you confided to us, the task of awarding the premium of £500, which you offered in 1855 for the best method of preventing smoke during the combustion of the coal of your district in marine engine boilers, has been so great, that we feel called upon to address you on the subject, although we are not yet in a position to report finally thereon.

2.—The experiments which it was necessary to make, required much time, as well as the construction of apparatus specially destined for the purpose; and at a very early period we became convinced that the only way in which we could satisfactorily decide the question referred to us, was to submit the designs brought before us, or such of them as we thought suitable, to trial on a boiler of the ordinary construction employed in steam vessels.

3.—Our first step, therefore, was to have such a boiler built; then to ascertain its effective power as a standard whereto to refer the effects of the various smoke preventing systems; and, finally, by a comparison of these results with such standard, to determine how far any of them, and if any, which of them, were entitled to the premium.

4.—We much regret that we are still unable to come to a final conclusion on this matter, but as in the course of our experiments we have arrived at some facts which we think it important to your interests to be made known, we beg to lay them before you, reserving to a future, and we trust not a distant, period, a more complete Report upon the whole subject.

5.—The results obtained establish the following facts:—

- 1st.—That the coal from your district, commonly called the “Hartleys,” may be consumed in ordinary multitubular marine boilers without making any smoke.
- 2nd.—That this may be done without the adoption of any of the various schemes which have been brought before us.
- 3rd.—That it does not involve any loss of power or economy, but that with a given boiler *more* water may be evaporated, whilst no smoke is made, than can be evaporated with the hardest firing on the usual system accompanied by a dense black smoke; and further, that the economic effect or the quantity of water evaporated by 1lb. of coal is greater when no smoke is being made to the extent of from 17 to 22 per cent.
- 4th.—That the combustion of the coal is perfect, and its evaporative power far beyond what has usually been ascribed to it.
- 6.—The first two statements are proved by the evidence of the senses, and we can appeal to numerous eye-witnesses of the operations at Elswick for their confirmation.
- 7.—The third and fourth are proved by the results of the experiments, which may be thus stated :—

FIRST SERIES.

Work Done.	Hard Firing. Much Smoke.	Hard Firing. No Smoke.
Coal burned per Square Foot of Fire Grate per Hour....	lbs. 18·50	lbs. 21
Water evaporated from 60° Fah. per Square Foot of Fire Grate per Hour.....	Cub. Feet. 2·197	Cub. Feet. 2·992
Total evaporation per Hour from 60° Fah.	Cub. Feet. 60·5	Cub. Feet. 83·5
Water evaporated from 212° Fah. by 1lb. of Coal	lbs. 8·61	lbs. 10·10

Shewing an increase of work done of 38 per cent. and a superior economy of fuel of 17 per cent. whilst making no smoke.

8.—In the above series of experiments we had—

Area of fire grate 28½ square feet.

Heating surface (total) 749 square feet.

Ratio of fire grate to heating surface 1 to 26½.

9.—After this, an alteration was made in the boiler. The fire grate

was reduced, and an apparatus attached, by means of which the feed water was partially heated by the waste gases of the chimney, making the proportion as follows:—

Area of fire grate.....19½ square feet.

Heating surface boiler749 square feet.

Heater320 " "

1069

Ratio of fire grate to heating surface1 to 55½.*

10.—The following table gives the results:—

SECOND SERIES.

Work Done.	Hard Firing. Much Smoke.	Hard Firing. No Smoke.
Coal burned per Square Foot of Fire Grate per Hour....	lbs. 21	lbs. 17·34
Water evaporated from 60° Fah. per Square Foot of Fire Grate per Hour.....	Cub. Feet. 2·909	Cub Feet. 2·937
Total evaporation per Hour from 60° Fah.	Cub. Feet. 56	Cub. Feet. 56½
Water evaporated from 212° Fah. by 1lb. of Coal	lbs. 10·06	lbs. 12·27

Shewing an increase of work of 1 per cent. and a superior economy of fuel of 22 per cent. whilst making no smoke.

11.—We have, therefore, no hesitation in saying, that the coals known as "Hartleys" may be consumed in ordinary multitubular marine boilers *without smoke, and with a large saving of fuel resulting from its prevention.*

12.—The evaporative power of the coal, as above stated, is much beyond what is usually attributed to it, and this fact will doubtless be the more gratifying to you, as it may serve to correct an error of opinion which has resulted from the published "Reports on Coals suited to the Steam Navy," with the high sanction of the names of Sir H. de la Beche and Dr. Lyon Playfair.

13.—In these reports the evaporative power of the coal under consideration, is stated at 7·495 lbs. of water evaporated from 212° Fah. by 1lb. of coal, and of the Welsh coals, on an average of 31 kinds, at 9·24lbs. of water per lb. of coal—the best of the Welsh coal being 10·37lbs. per lb. of coal.

* This is including the heater as heating surface.

14.—Some part of the great difference between these and our own results may doubtless be attributable to the different circumstances under which the coals were tried, but we submit, that the results we have arrived at, (the experiments being made with a boiler of the ordinary multitubular construction, as generally used for marine engines) are, as *practical data*, superior to those made by the Government Officials on a much smaller scale, and with an apparatus such as is never used for marine purposes.

15.—We were not, indeed, called upon to pronounce upon the comparative values of the Welsh and North Country coals, but seeing the startling discrepancy between our results and those of the Government experiments, amounting to no less than 65 per cent. as regards your coals, we have felt it necessary to make actual trial of the Welsh coal in the same boiler.

16.—These experiments are still in progress, and in our next report, we hope to give the details, and to discuss fully the whole question.

17.—We are at present however able to state, that under the most favourable conditions, the Welsh coal *does not exceed the Hartleys either in the amount of work done in a given time, or in economy, and under the general circumstances of Steam Navigation, falls short in both particulars.*

18.—It will give us great pleasure if, in our next report, we are able to announce a still higher evaporative power in the North Country coals, resulting from some one or more of the plans for Smoke Prevention submitted to us; but it is only right to state that from the analysis of the gases escaping from the chimney during the above recorded experiments, we can scarcely anticipate any considerable increase of calorific effect beyond what we have already obtained.

We have the honour to be, Gentlemen,

Your most obedient Servants,

JAMES A. LONGRIDGE,

17, Fludyer Street, Westminster.

W. G. ARMSTRONG,

Newcastle-upon-Tyne.

THOMAS RICHARDSON,

Newcastle-upon-Tyne.

Newcastle-upon-Tyne, 25th August, 1857.

SECOND REPORT.

TO THE STEAM COAL COLLIERIES' ASSOCIATION,
NEWCASTLE-UPON-TYNE.

GENTLEMEN,—

(1.)—In submitting to you our further Report upon the question which you have referred to our decision, we have to observe that it would have been easy for us to have selected and submitted to trial certain of the competitors' plans, and to have reported to you on their comparative merits at a much earlier period. But such a course would neither have done justice to you nor to the important question which we had to decide, inasmuch as one of the principal conditions established for the competition, was that the plans submitted should not diminish the evaporative power of the boiler.

(2.)—It was, therefore, our first object to ascertain this evaporative power as a standard of reference.

(3.)—The boiler built for these experiments presented no peculiar features. The annexed drawing will show that it was the ordinary type of a marine multitubular boiler, such as is generally considered to present the greatest difficulty as regards the prevention of smoke.

(4.)—It contained two furnaces, each three feet wide, and 135 tubes $5\frac{1}{2}$ feet long and three inches internal diameter, and had an aggregate heating surface of 749 square feet.

(5.)—The heater, which was subsequently added, as mentioned in the ninth paragraph of our former Report, was used for the purpose of heating the feed water. It in no way altered the condition of the boiler, except by reducing the temperature of the escaping gases, and thereby, to some extent, diminishing the draught and rendering the prevention of smoke somewhat more difficult, whilst, at the same time, it slightly increased the evaporative effect by its additional absorbing surface.

(5a.)—This increase was, however, much less than might have been expected from the large absorbing surface of the heater, which contained 320 square feet; yet it was found that, when the products of combustion before entering the heater were at 600°, the passage through it did not reduce the temperature more than about 40° to 50°.

(6.)—The whole of the experiments with the competitors' plans were made with the boiler after the heater was added, as also were those made previously for establishing the standard of reference.

(7.)—We did not fix upon any specific amount of fire grate surface, but left it perfectly free to each competitor to adopt such amount as he deemed best suited to his own plan, and we furnished to each competitor whose plan was tried, a drawing of the boiler, and requested him to arrange the details according to his own judgment, and to be present at, and take the entire charge of, the experiments by the result of which his plan was to be judged.

(8.)—With the object of securing to all parties perfect equality, we took care that the whole of the coal used was obtained from the same colliery, and was supplied in its ordinary state for shipment.

(9.)—The following were the conditions previously fixed upon, and advertised by you as those which should be complied with, in order to entitle any competitor to the premium:—

“No design shall be deemed entitled to the premium unless it be in conformity with the following conditions” :—

(a.)—It shall effectually prevent the production of smoke during the combustion of any of the Hartley steam coals of the North of England.

(b.)—Such prevention shall be accomplished by the combustion of the smoke or gases in the furnace or air chamber previous to passing through the flues or tubes.

(c.)—It shall be applicable to all the usual forms of boiler, containing a number of small tubes between the furnace and the chimney, and especially to the usual forms of marine boilers.

(d.)—It shall not diminish the evaporative power of the boiler to which it may be applied.

(e.)—It shall not impair the durability of the boiler.

(f.)—It shall, as far as possible, be independent of the personal attention of the stoker or engineer, but it is not essential that it should be absolutely so.

(g.)—It shall not be, or be made, the subject of a patent, or, if so,

the inventor or patentee shall undertake that the patent right shall not exceed in amount such rate per horse power or per foot of fire grate as the judges may determine.

(10.)—In the month of August, 1855, we met for the purpose of arranging our proceedings, and made a cursory examination of the plans which had been sent in, rejecting those which were obviously either inapplicable or impracticable. To the authors of the others, we addressed a circular through your secretary, stating that their plans were retained for further consideration.

(11.)—As soon as the boiler was ready we proceeded to experiment upon it in order to determine the standard of reference. Much time was occupied in these trials and in the course of them we arrived at the striking results already communicated in our first Report, viz., *that the evaporative power of the coal was much greater than had been previously stated, and that smoke could be prevented with ease, and at the same time with a decided advantage to the effective power of the boiler.*

(12.)—In all these and the subsequent experiments the details were carefully registered, the whole of the coals weighed and water measured. The weights of ashes, cinders, and clinkers which were left were weighed. Diagrams of the temperature of the escaping gases obtained by a pyrometer, and a number of other particulars recorded which would occupy too much space to enter upon in this Report.

(13.)—Although we arrived at results exceeding in some respects those obtained by any of the competitors, we have not thought it fair to take our *best* results as the standards of reference, because, being the issue of a long series of carefully conducted experiments, we felt that to take these results as standards would be going beyond the spirit, though not perhaps beyond the letter of the published conditions.

(14.)—We have, therefore, established as the standard the means of a series of experiments during which the firing was conducted according to the ordinary system, every care, however, being taken to get the maximum of work out of the boiler by keeping the fire grates clean and by frequent stoking. No air was admitted except through the fire-grates, and as a consequence much, and often a very dense smoke was evolved.

(15.)—As the economic effect of the fuel increases when the ratio of the fire-grate surface to the absorbing surface is diminished, we have adopted two sizes of fire-grates, and consequently two standards of reference. With the larger fire-grate the amount of work done by the

boiler per hour is greatest, but this is done at a relative loss of economic value of the fuel as compared with the smaller grate.

The one gives us the standard of maximum evaporative power of boiler,—the other the standard of maximum economic effect of the fuel.

The fire surfaces used for fixing those standards were $28\frac{1}{2}$ and $19\frac{1}{2}$ square feet respectively.

(16.)—Each competitor was allowed to vary his fire-grate to meet these two standards, and in the tabulated forms hereinafter given, the results obtained are compared with the standards as well as with the maximum results which we have arrived at in our own experiments.

(17.)—With these prefatory remarks we now proceed with our report.

(18.)—The total number of plans submitted to us was 103, which, upon examination, we found might be arranged in the following classes :

1st Class.—Requiring no special apparatus and depending upon the admission of *cold* air into the furnace or at the bridge.

2nd Class.—Requiring no special apparatus, and depending upon admission of *hot* air into the furnace or at the bridge.

3rd Class.—Requiring special adaptations of the furnace of more or less complexity, but yet applicable to the ordinary type of marine boiler. The most of this class admitting air above the fire-grate surface.

4th Class.—Requiring self-acting or mechanical apparatus for supplying the fuel.

5th Class.—The smoke burning systems, the principle of which is to pass the products of combustion through or over a mass of incandescent fuel. This class might be subdivided into two, in one of which the gases pass downward through a part of the fire-grate into a close ash-pit, and thence to the flame chamber or tubes, and in the other the gases, &c., from one furnace are passed into the ash-pit and upwards through the fire-grate of another furnace, and in which arrangement the process is alternated by a system of doors or dampers.

6th Class.—Proposing the admission of steam mixed with the air into the furnace as a means both of preventing smoke and increasing the evaporative effect of the fuel.

7th Class.—Such projects as are either impracticable or not applicable to the ordinary type of marine boilers, and consequently not in accordance with the established conditions.

(19.)—The following table shews the number of plans sent in arranged in the above classes :—

Class 1	9
„ 2	16
„ 3	15
„ 4	6
„ 5	12
„ 6	1
„ 7	44
	<hr/> 108

(20.)—Before proceeding with the results of the trials, we beg to offer some remarks upon the principles involved in these various systems.

(21.)—In the first place it may be remarked that absence of smoke is no sign of perfect combustion. Invisible gases may be passing away unconsumed for want of a sufficient supply of oxygen, and thus a loss of heating effect result, which will show itself in the diminished evaporative effect of the fuel. Practically, whenever the air is supplied solely through the bars this result, or the production of visible smoke, will ensue, and this is recognized by all those whose plans fall under classes 1 and 2, as well as by many whose schemes are comprised in the other classes.

(22.)—But we here meet with an important distinction. The advocates of Class 1 maintain that *cold* air should be admitted, whilst those of Class 2 hold that the air should be previously *heated*.

(23.)—It is not our intention at present to enter into any discussion of this question, but simply to state our conviction that the advantage (if any) resulting from such previous heating of the air is attended with such practical inconveniences as lead us to give a decided preference to the plans included in Class 1.

(24.)—With respect to Class 3 it is obvious that it is inferior to Class 1 in so far as it requires a special apparatus of more or less complexity and involves greater expense both in first cost and in maintenance. Unless then it can be shown that it is in other respects superior to Class 1 it must be rejected.

(25.)—The plans of the 4th Class possess the merit of requiring less attention from the workmen than any of the others, and, under certain circumstances, may be adopted with advantage.

When a regular supply of steam is required some of these will be found very efficient, and we may name Jucke's, Knowelden's, and Hall's as likely to give very good results, but for marine boilers, where space is

limited and the amount of steam required very variable, we think they are inferior to the more simple system included in Class 1.

(26.)—The 5th Class we are compelled to reject as wrong in principle, and, under several of the forms submitted to us, quite impracticable.

The mere passing of the gases unmixed with air through a mass of incandescent fuel will not destroy the smoke, or if they be so mixed, still, in passing through the fuel, carbonic oxide will generally be formed, and thus a loss of heat will be evolved although visible smoke be prevented. This is attempted to be met, in some cases, by the introduction of fresh air to the gases after passing through the fire.

(27.)—There is, moreover, a very serious objection to many of the plans of this class which does not seem to have had due weight with the projectors, viz., the destructive action of the flame and heated gases upon the bars which support the fire through which they are passed. In some cases it is supposed that this will be obviated by using hollow bars through which a current of air is passed. This would prove utterly inefficient. In other cases it is proposed to make the bars of tubes filled with water, and thus forming part of the heating surface of the boiler. This involves considerable practical difficulties in the construction, and particularly in any repairs which may be needed, and we consider these difficulties to be of sufficient magnitude to render it highly injudicious to adapt such a system in marine boilers where the failure of one of these tubular bars during the voyage might render the boiler entirely useless.

(28.)—Of Class 6 only one example was brought before us. We think the author of this plan to be wrong in principle, because the mere action of heat will not decompose steam, and, even if it would, it is difficult to understand how any advantage could be gained by the hydrogen of the steam parting with its own oxygen simply to take up the same amount from the air which is introduced along with it. If the steam be introduced below the fire grate and the bars be red hot there is no doubt that it might be partially decomposed, but this would be at the expense of oxydizing the iron of the bars and they would be rapidly destroyed.

(29.)—The 7th Class calls for no further remark than that the plans included in it are inapplicable to marine boilers.

(30.)—After full consideration we selected the following plans for trial at your expense :—

From Class 1.—Messrs. Hobson & Hopkinson, Huddersfield.

Mr. C. W. Williams, Liverpool.

Mr. B. Stoney, Dublin.

From Class 3.—Mr. Robson, of South Shields.

(31).—We did not feel ourselves justified in trying any of the other plans at your expense, but in acquainting the remaining competitors with our decision we stated that we were ready to submit their plans also for trial if they desired it, in conformity with the fifth paragraph of the original advertisement. None of these parties, however, availed themselves of the opportunity thus given of testing their plans at their own expense.

(32).—The standard of reference alluded to in the 14th and 15th paragraphs of the present report are as follows:—

	Fire Grate 28½ Square Feet.		Fire Grate 19½ Square Feet.	
	A	B	A	B
Economic value, or lbs. of water evaporated from 212° by 1lb. of coal	9.41	11.15	10.06	12.58
Rate of combustion, or lbs. of coal burned per hour per square foot of fire grate	21.15	19.00	21.00	17.25
Rate of evaporation per square foot of fire grate per hour in cubic feet of water from 60°	2.62	2.93	2.909	2.995
Total evaporation per hour in cubic feet of water from 60°	74.80	79.12	56.01	57.78

The columns A contain the standards of reference alluded to in paragraph 15, whilst the columns B give the *mean of the best* results obtained by our own experiments *when making no smoke*.

(33).—The first plan submitted for trial, was that of Mr. Robson, of Shields, which we selected as a type of several of the plans comprised in Class 3, and as in our opinion the most likely of its kind to prove successful. The principle of this plan is to divide the furnace into two fire-grates, the one at the back being shorter than the other, and placed at a lower level. This back grate is furnished with a regular door-frame and door, for the purpose of enabling the stoker to clean the bars and remove the clinker when required. This door is also provided with an aperture fitted with a throttle valve, and in the inside a distributing box perforated with half-inch holes, after the manner practised by Mr. Wye Williams. The front grate is like the ordinary fire-grate, but without any bridge. The mode of proceeding is to throw all the fresh coal upon the front grate, and to keep the back or lower grate supplied with cinders, or partially coked coal, which is pushed on to it from time to time from the

upper or front grate. No air is admitted at the door of the upper grate, but the gases arising from it meet with the current of fresh air admitted through the door of the lower grate, and in passing over the bright fire upon it are to a greater or less degree consumed.

(34).—With respect to absence of smoke, we have to report that this plan is only partially successful. It diminishes the amount of smoke considerably, but it requires careful and minute attention from the stoker, otherwise, a good deal of smoke at times appears, and particularly when fresh fuel is pushed forward from the upper to the lower grate.

(35).—Mr. Robson's fire-grate surface was $32\frac{1}{2}$ square feet.

(36).—As regards economic value of fuel and work done, the following was the result:—

Economic value of fuel10·70 lbs.
 Rate of combustion15·50 „
 Rate of evaporation per square foot per hour ..2·14 cubic feet.
 Total evaporation from 60° ditto ..70·50 „

(37).—Comparing these results with the standard, we get

	Robson.	Standard.	More.	Less.
			Per Cent.	Per Cent.
Area of fire-grate	32·50	28·50	14·03	....
Economic value of fuel ..	10·70	9·41	13·7	....
Rate of combustion	15·52	21·15	....	26·7
Rate of evaporation	2·14	2·62	....	18·4
Total evaporation	70·50	74·80	....	5·8

(38).—From this it appears that though there was an increase of economic value of fuel to the extent of 13·7 per cent., there was a loss of work done by the boiler to the extent of 5·8 per cent., and this, although the fire-grate was greater by four square feet, or 14 per cent.

(39).—This result may be traced to the nature of the apparatus. Owing to the large admission of air at the fire-door of the lower or back grate requisite to prevent smoke, the fuel on the front grate burns sluggishly, and hence the falling off in the rate of combustion and the work done.

(40).—The heat in the back grate was very intense, but the generation of heat being thus thrown nearer to the tubes, the effect of the absorbing surface above the front grate was greatly impaired.

(40a).—We think also that the very intense heat in the back grate would be more injurious to the boiler and the tubes than the more equally distributed temperature which results from the ordinary description of fire-grate.

(41).—Another objection to this system is the constant attention required from the stoker, to keep the fires in order, and the difficulty in removing the clinker from the back grate, where it tends to form in considerable quantity.

(42).—The next plan submitted to trial, was that of Messrs. Hobson and Hopkinson, of Huddersfield. In this system air is admitted both at the doors and at the bridge. At the doors by means of vertical slits, which may be opened or shut at will by a sliding shutter, and at the bridge through apertures in hollow brick pillars placed immediately behind it. The entrance of the air to these pillars is regulated by throttle valves, worked by a lever in the ash-pit. There are also masses of brick-work placed in the flame-chamber, with the intention partly of deflecting the currents of gases, so as to ensure their mixture with the air, and partly to equalize the temperature.

(43).—As regards prevention of smoke, we have to report that this plan was very efficient, though in hard firing it required considerable attention from the stoker. Whilst burning about 15 lbs. of coal per square foot of grate per hour *no smoke* was visible, even with ordinary firing, but when the quantity was increased to $21\frac{1}{2}$ lbs. per square foot per hour, the fire required to be very carefully attended to, or smoke, though in no great quantity, began to appear.

(44).—Messrs. Hobson and Hopkinson's fire-grate surface was originally $27\frac{1}{2}$ square feet, but this was subsequently reduced to $18\frac{1}{2}$ square feet.

(45).—As regards economic effect and work done, the following were the results:—

	Fire Gate, 27½.	Fire Grate, 18½ Sq. Feet.
	lbs.	lbs.
Economic value of fuel	11·08	11·70
Rate of combustion	14·25	21·50
Rate of evaporation per square foot per hour from 60°	Cubio Feet 2·18	Cubio Feet. 3·49
Total evaporation from 60°	60·03	63·62

(46).—Comparing these results with the standards we get

LARGE FIRE GRATES.				
	Hobson & Hopkinson.	Standard.	More.	Less.
	Feet.	Feet.	Per Cent.	Per Cent.
Area of fire grate	27·5	28·5	....	3·7
	lbs.	lbs.		
Economic value	11·08	9·45	17·1	....
Rate of combustion	14·25	21·15	....	32·7
	Cubic Feet.	Cubic Feet.		
Rate of evaporation	2·18	2·62	....	16·8
Total evaporation	60·03	74·80	....	19·8

SMALL FIRE GRATES.				
	Hobson & Hopkinson.	Standard.	More.	Less.
	Feet.	Feet.	Per Cent.	Per Cent.
Area of fire grate	18·25	19·25	....	5·2
	lbs.	lbs.		
Economic value	11·70	10·06	16·3	....
Rate of combustion	21·50	21·00	2·3	....
	Cubic Feet.	Cubic Feet.		
Rate of evaporation	3·49	2·909	19·9	....
Total evaporation from 60°	63·62	56·01	13·5	....

(47).—From these tables it appears that with the large fire grate there was an increase of economic value of fuel, although less work was done, whilst with the small grates there was a decided increase both of economic value and of work. Had the fires been harder pushed with the large grate, we have no reason to doubt that, although the economic value would have been somewhat less, the work done would have been up to the standard.

(48).—The only objection to this system is that the brickwork is liable to crack and get out of repair, but we do not attach much importance to this, as we believe that the existence of this brickwork is of no consequence, and that the results obtained are due simply to the admission of air to the gases.

(49).—The system is applicable to all the usual forms of boilers, the combustion is very good, and, with moderate firing, it does not much de-

and upon the stoker, and we are therefore of opinion that it complies with all the prescribed conditions.

(50.)—The next plan tried was that of Mr. C. Wye Williams, of Liverpool.

Mr. Williams' system, as is well known, consists in the admission of air at the furnace door, or at the bridge, or at both, by numerous small apertures, with the intention of diffusing it in streams and jets amongst the gases. In the plan adopted in the present instance, Mr. Williams introduces the air only at the front of the furnace, by means of cast iron casings, furnished on the outside with apertures provided with shutters so as to vary the area at will, and perforated in the inside with a great number of half-inch holes. The mode of firing, which Mr. Williams adopts, merely consists in applying the fresh fuel alternately at opposite sides of the furnace so as to leave one side bright whilst the other is black.

(51.)—The original fire grate proposed by Mr. Williams was twenty-two square feet, which was subsequently reduced to eighteen square feet.

(52.)—As regards economy of fuel and work done, the following were the results :—

	Fire Grate, 22 sq. Feet.	Fire Grate, 18 sq. Feet.
Economic value of fuel	lbs. 10·84	lbs. 11·30
Rate of combustion	26·98	27·36
Rate of evaporation	Cubic Feet. 4·04	Cubic Feet. 4·31
Total evaporation	88·96	76·92

(53.)—Comparing these results with the standards, we get

LARGE FIRE GRATE.				
	Williams.	Standard.	More.	Less.
	Feet.	Feet.	Per Cent.	Per Cent.
Area of fire grate	22·0	28·5	....	24
Economic value of fuel ..	lbs. 10·84	lbs. 9·45	11·5	....
Rate of combustion	26·98	21·15	27·4	....
Rate of evaporation	Cubic Feet. 4·04	Cubic Feet. 2·62	54·2	....
Total evaporation	88·96	74·80	19	....

SMALL FIRE GRATE.				
	Williams.	Standard.	More.	Less.
	Feet.	Feet.	Per Cent.	Per Cent.
Area of fire grate	18·00	19·25	....	6·5
	lbs.	lbs.		
Economic value	11·30	10·06	12·3	....
Rate of combustion	27·36	21·00	30·3	....
	Cubic Feet.	Cubic Feet.		
Rate of evaporation	4·31	2·909	48·0	....
Total evaporation	76·92	56·01	37·3	....

(54.)—These results shew a large increase above the standard in every respect.

(55.)—The prevention of smoke was, we may say, practically perfect, whether the fuel burned was 15lbs. or 27lbs. per square foot per hour. Indeed in one experiment we burned the extraordinary quantity of 37½lbs. of coal per square foot per hour upon a grate of 15½ square feet, giving a rate of evaporation of 5½ cubic feet of water per hour per square foot of fire grate, without producing smoke.

(56.)—No particular attention was required from the stoker, in fact, in this respect, the system leaves nothing to desire, and the actual labour is even less than that of the ordinary mode of firing.

(57.)—Mr. Williams' system is applicable to all descriptions of marine boilers, and its extreme simplicity is a great point in its favour.

(58.)—It fully complies with all the prescribed conditions.

(59.)—The next and last plan submitted to trial was that of Mr. B. Stoney, of Dublin.

In principle so far as regards the prevention of smoke by the admission of air through the doors, and at the front of the furnace, this plan is identical with that of Mr. Williams'. Its peculiarity consists in the adoption of a shelf outside the boiler, forming in fact, a continuation of the dead plate outwards. Upon this shelf the fresh charge of coals is laid in a large heap, about half of the heap being within the furnace, and the rest outside. The door is a sliding frame, which shuts down upon the top of this heap of coals, so that air is admitted through the body of the coals as well as through perforations in the front plate of the furnace. When *the furnace requires fresh fuel*, a portion of that forming the heap, and *which, to some extent has parted with its gases, is pushed forward and its place made up by fresh fuel laid on in front.*

(60.)—This plan did not succeed in preventing smoke, for whenever the coal was pushed forward upon the fire, dense smoke was evolved.

We regret that Mr. Stoney was not personally present to see the result, which we think would have entirely satisfied him, that the method he proposed, did not comply with this important condition. Under these circumstances, we did not proceed to determine the economic value of the fuel or work done by this system.

(60a.)—In the following tables the results in each case are compared with the standards, and also with those of our own experiments when making no smoke. The former marked A, and the latter B.

LARGE FIRE GRATES.					
	A. Standard.	B. Our expmt.	Robson.	Hobson and Hopkinson.	Williams.
Area of grate, square feet	sq. feet. 28½	sq. feet. 28½	sq. feet. 32½	sq. feet. 27½	sq. feet. 22
Economic value of fuel or water evaporated from 212° by 1 lb.	lbs. 9.41	lbs. 11.15	lbs. 10.27	lbs. 11.08	lbs. 10.84
Rate of combustion per square foot of grate per hour	21.15	19.00	15.52	14.25	26.98
Rate of evaporation per square foot of grate per hour from 60°..	cub. feet. 2.62	cub. feet. 2.93	cub. feet. 2.14	cub. feet. 2.18	cub. feet. 4.04
Total evaporation in cubic feet per hour from 60°	74.80	79.12	69.52	60.03	88.96

SMALL FIRE GRATE.					
	A. Standard.	B. Our Expr.	Robson.	Hobson and Hop- kinson.	Williams.
Area of Grate	sq. ft. 19½	sq. ft. 19½	Small grate not tried.	sq. ft. 18½	sq. ft. 18
Economic value of fuel or water e- vaporated from 212° by 1lb. of coal .. }	lbs. 10.06	lbs. 12.58		lbs. 11.70	lbs. 11.30
Rate of combustion per sq. ft. of grate } per hour	21.00	17.25		21.50	27.36
Rate of evaporation per sq. ft. of grate } per hour	c. ft. 2.909	c. ft. 2.995		c. ft. 3.49	c. ft. 4.31
Total evaporation per hour	56.01	57.78		63.62	76.92

(61.)—With the above results before us we are unanimously of opinion

that Mr. Williams must be declared the successful competitor, and we therefore award to him the premium of £500 which you offered by your advertisement of 10th May, 1855.

(62.)—It is true that in economic value of fuel the *tabulated* results of Mr. Williams' trials are about 2 per cent. inferior to those of Messrs. Hobson and Hopkinson, but on the other hand the amount of work done is much greater.

By Mr. Williams' plan the quantity of water evaporated with a 22 feet grate, was 48 per cent. greater than with the 27 feet grate used in Messrs. Hobson and Hopkinson's case, and 20 per cent. more with an 18 feet grate.

(63.)—We should also mention that in an experiment not tabulated, Mr. Williams obtained an economic value of 11·70, and a total evaporation of 61·59 cubic feet, with a 22 feet fire-grate, results which exceed those of Messrs. Hobson and Hopkinson's experiments, with 27½ feet fire-grate and equal in economic value of fuel their results with 18 feet fire-grate.

(64.)—An important feature in Mr. Williams' system is that it may be successfully applied under very varied circumstances. We have above given results obtained with fire-grates of 22 square feet and 18 square feet, but in order to test the matter still further we reduced the fire-grate to 15½ square feet, with the following result:—

Area of fire-grate.....	15½ square feet.
Economic value of fuel	10·66 lbs.
Rate of combustion per square foot of grate } per hour	37·4 lbs.
Rate of evaporation per square foot of grate } per hour	5·51 cubic feet
Total evaporation per hour.....	85·30 ,,

(65.)—The results which we ourselves obtained exceed, in economic value of fuel, all the results of the experiments made with the competitors, plans. This was chiefly the case with the small fire-grates, and was due in a great degree if not altogether, to the smaller amount of fuel burned per square foot of grate per hour.

The consequence of this was a more complete *absorption* of the heat generated, so that the products of combustion escaped from the chimney at a temperature lower by about 200° when we obtained our best economic results, than they did during the trials of the competitors' plans. It must be remembered that this increase in the economic value of the

fuel is obtained at the expense of the work done, but it is highly satisfactory to find that (as is shown in columns A and B of the last tables,) *the great increase in the economic value, is also accompanied with a decided increase in work done when perfect combustion is attained and smoke prevented.*

(66.)—We may now be expected to say a few words on the circumstances and mode of proceeding which we adopted, and by which we got the results contained in the columns marked B.

They may be briefly described under these heads :—

1st.—The fire grate.

2nd.—The fire door.

3rd.—The mode of firing.

(67.) (1.)—The fire bars which we found most successful were cast about half an inch thick on the top, and as thin as possible at the bottom, and with the ends thickened up so as to leave about five-eighths or three-quarters of an inch air space.

(68.) (2.)—The fire doors were the ordinary doors, perforated with horizontal slits about half an inch wide and fourteen inches long, for the admission of air.

(69.) (3.)—Our mode of firing may be described as follows :—The coal was applied in charges of one cwt. each, and was all thrown on to the dead plate, which was sixteen inches deep, and remained there until the furnace was again ready for charging. This coal, which had then, to a great extent, lost its hydro-carbons, was pushed forward with the rake, and a new charge thrown on the dead plate, to remain there until the furnace was again ready. The grates were always kept covered with ignited fuel to a depth of ten to twelve inches, and the furnaces worked alternately as nearly as convenient, although this was by no means of consequence as regards the prevention of smoke.

(70.)—All the ashes that fell through the bars were raked forward, and thrown on to the fire with the fresh coals, so that the ash-pit was kept clear and cool, and the whole of the cinders burned. The result of this was, that the average amount of ash to be removed from the ash-pit and thrown away did not exceed 1·1 per cent. of the coal used.

(71.)—The amount of clinkers averaged about 1·85 per cent. of the fuel used.

(72.)—No stoking was required beyond occasionally gently raising the coals before firing with the poker, and it is worthy of remark that the heap of raw coal on the dead plate keeps the fire doors perfectly cool.

(73.)—This mode of firing we find extremely efficient, and certainly requires nothing beyond such an amount of attention as may reasonably be expected from any working man of ordinary intelligence, and the actual labour is very much less than under the pernicious system to which men of this class are so wedded.

(74.)—The admission of air at the doors is simply an adaptation of the principle so long advocated by Mr. Williams, and we prefer his arrangement for this purpose to that which we had previously used.

(75.)—From the preceding observations it will be seen that there is no real difficulty in the prevention of smoke. The arrangements of the furnace are simple in the extreme and not liable to derangement, beyond this, all that is required is a man of moderate intelligence, *willing to be taught and ready to obey orders*. No extra labour is required at his hands, nothing beyond regular attention to a prescribed but simple mode of working.

(76.)—But unless such men are properly instructed and then kept to their duty, it is in vain to expect satisfactory results.

(77.)—The management of a furnace is an art, though a very simple one, but, like every other art, its rules must be regarded.

(78.)—Of its importance we need not say more than that bad construction and negligence may easily reduce by one-third the economic value of the fuel and the evaporative power of the boiler.

(79.)—Before concluding we might offer some further observations upon the results we have obtained, and on various interesting and important questions which have presented themselves during the course of our enquiries, but to do so in a manner at all satisfactory would be impossible within the limits of a Report like the present.

(80.)—We must, therefore, content ourselves with pointing out three chief conclusions at which we have arrived, and which, we believe, will prove of great advantage as well to your interests as to those of all connected with steam navigation.

(81.) 1st.—*That by an easy method of firing, combined with a due admission of air in front of the furnace, and a proper arrangement of fire grate, the emission of smoke may be effectually prevented in ordinary marine multitubular boilers whilst using the steam coals of the "Hartley District" of Northumberland.*

(82) 2nd.—*That the prevention of smoke increases the economic value of the fuel and the evaporative power of the boiler.*

(83.) 3rd.—*That the coals from the Hartley District have an eva-*

porative power fully equal to the best Welsh steam coals, and that practically, as regards steam navigation, they are decidedly superior.

(84.)—This last conclusion is contrary to the general opinion, which, based upon the Reports presented to Government by Sir H. de la Beche and Dr. Lyon Playfair, is strongly in favour of Welsh coal.

(85.)—The effect of those Reports has been to do the Northumberland coal-field an immense injury, and we feel this so strongly that we beg to lay before you a few observations on the subject in a short supplementary Report accompanying this.

(86.)—We cannot conclude this Report without bringing to your notice the services of Mr. William Reed, to whom we entrusted the practical management of the long series of experiments which we deemed it right to make.

(87.)—To his intelligence and unwearied attention we are much indebted, and we can only add that we have every reason to congratulate ourselves and you upon having had the benefit of his valuable assistance throughout the whole of this long and important enquiry.

We have the honor to be, Gentlemen,

Your obedient Servants,

JAS. A. LONGRIDGE,
18, Abingdon Street, Westminster.

W. G. ARMSTRONG,
Newcastle-on-Tyne.

THOMAS RICHARDSON,
Newcastle-on-Tyne.

Newcastle-on-Tyne, 16th January, 1858.

THIRD REPORT.

TO THE STEAM COAL COLLIERIES' ASSOCIATION,
NEWCASTLE-UPON-TYNE.

GENTLEMEN,

(1.)—In our Report to you, dated 25th August, last, we drew your attention to certain results which we had obtained in the course of our experiments, shewing that the evaporative power of the coal of your district is much beyond what is usually attributed to it, and we stated that this fact might serve to correct an error of opinion which has resulted from the published Reports on coals suited to the steam navy, with the high sanction of the names of Sir H. de la Beche and Dr. Lyon Playfair.

(2.)—The coals upon which Dr. Lyon Playfair and his colleague made their experiments, included those from the collieries called respectively, West Hartley Colliery, and Aberaman Merthyr, the former representing an average quality of the North Country Steam Coal, and the latter the best Welsh.

(3.)—The results arrived at as regards the relative calorific values of these coals were as follow :—

Aberaman Merthyr	10·75
West Hartley	7·87

(4.)—In a letter addressed to the Editor of, and published in the Journal of the Society of Arts, in October, 1857, Dr. Playfair, while not attempting to impugn our results, explains their discordance with those obtained by himself and Sir H. de la Beche, by affirming that they did not profess to give the *absolute* values of the coals tried, but only their *relative* values under like conditions of experiment. He further states, that attention was drawn to the unfitness of the small Cornish boiler used, to give *absolute* results, and he adds, that he would not be surprised to learn that it was fifty per cent. below a multitubular boiler.

(5.)—This explanation of Dr. Playfair's appears to imply, that, although

the figures given in the Reports do not express *absolute* calorific effects, they correctly indicate the *relative* values of the respective coals. But this conclusion, which is at direct variance with our results, appears to be completely vitiated by the fact admitted by Dr. Playfair, that instead of treating each kind of coal in the manner most favourable to the development of its powers, they based their determinations "*upon like conditions of experiment*" applied indiscriminately to both.

(6.)—Had the experiments been made with a proper marine boiler, instead of "a small Cornish boiler" — if a complete apparatus such as we employed had been used, and if the conditions necessary to effect perfect combustion of each kind of coal had been investigated and applied—we have no doubt that their results would have agreed with ours; but, as it is, we submit that our own more careful deductions are entitled to preference.

(7.)—Having obtained from you a cargo of the best Welsh coal, we proceeded to test its evaporative power, and have advanced sufficiently far to be justified in stating that the highest economic value we have been able to obtain from it is 12·35 lbs. of water evaporated from 212°, whilst with the Hartleys it was 12·90 lbs.; but we could only get this result from the Welsh coal by hand picking it, and rejecting the small, amounting to about 20 per cent. of the whole, whilst with the Hartley coal there was no waste whatever.

(8.)—If the proportion of 7·87 to 10·75 were the true *relative value*, it follows that the Welsh coal should have evaporated $12·90 \times \frac{10·75}{7·87} = 17·64$ lbs.; and if to this we add the heat carried off by the products of combustion through the chimney, which would be about equal to the evaporation of $2\frac{1}{2}$ lbs. of water, we should arrive at the actual heating power of 19·87 lbs. of water from 212°.

(9.)—Now, in the first Report by Dr. Playfair and his late colleague, they give a formula for calculating the theoretical value of coal, that is to say, the total weight of water which could be evaporated from 212° by the perfect oxydation of the hydrogen and carbon contained in the coal as determined by analysis.

(10.)—According to this formula the theoretic value of the Aberaman Merthyr, is 15·18 lbs. But on the hypotheses of 7·87 and 10·75 being true relative values, we ought to get a practical result for this coal of 19·87 lbs., that is to say, a practical result exceeding the theoretic or ultimate possible value by not less than 31 per cent.

(11.)—By the same formula the theoretic value of the average of six sorts of Hartley Coals comes out 14·051. But we have actually obtained 12·91 by evaporation, and the heat carried off by escaping gases was equivalent to a further evaporation of about 1·80lbs., giving a total practical result of $12·91 + 1·80 = 14·71$ lbs. as against 14·051, the theoretic or ultimate possible value of the Hartley Coal by the formula, being an excess of about 5 per cent.

(12.)—Assuming then that the formula is wrong to this extent, and applying the correction to the theoretic value of the Aberaman Merthyr, as above it would become $15·18 + ·759 = 15·94$, being still about 20 per cent. below the practical result, if *the proportions of 7·87 to 10·75 be true*.

(13.)—From our experiments with the Welsh Coal, we feel disposed to take its practical evaporative power when hand-picked and the small rejected at 12·35, but when used after the rejection of so much only of the small as will pass through a riddle having spaces of $\frac{3}{8}$ inch, a considerable reduction must be made.

(14.)—Adding to the above the heat escaping in the gases, we get the calorific values as follows:—

Hand-picked and small rejected 12·30 transmitted to the water + 2·30 escaping in the gases = 14·60lbs.

(15.)—As a check upon the other results, we have ascertained the absolute calorific effect of these coals by means of an apparatus constructed by Mr. Wright, of Millbank, Westminster, so contrived that a portion of coal is burned under water, and the products of combustion actually passed through the water, so that the whole of the heat generated is absorbed.

(16.)—By this apparatus we get the following calorific value:—

Welsh Coal 14·30 lbs. from 212°

Hartley Coal 14·63 lbs. „ „

Comparing these results with the others we get—

NAME OF COAL.	CALORIFIC VALUES.			Practical Economic Value.
	By Dr. Playfair's Formula.	By Wright's Apparatus.	By Deduction from our Experiments.	
WELSH COAL } Hand picked }	15·18	14·30	14·60	12·35
HARTLEY COAL } Large & Small together }	14·05	14·63	14·71	12·91

